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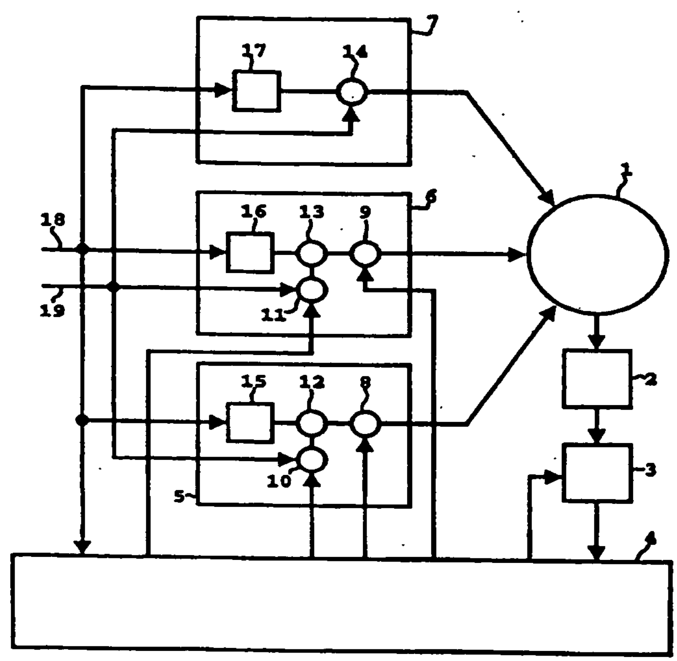
(54) Title: METHOD FOR REMOVING TORQUE VIBRATIONS IN AN AC MOTOR CONTROLLED BY A FREQUENCY CONVERTER

(57) Abstract

Method for eliminating torque vibrations in a frequency converter controlled a.c. motor used in an elevator system. In the method, the torque vibrations are minimised on the basis of the characteristic frequency of the motor supply current and its harmonics, which are separated from a suitable vibration spectrum descriptive of the elevator properties.



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METHOD FOR REMOVING TORQUE VIBRATIONS IN AN AC MOTOR CONTROLLED BY A FREQUENCY CONVERTER

The present invention relates to a method as defined in the preamble of claim 1 for eliminating torque vibrations in a frequency converter controlled a.c. motor used in an elevator.

A feature characteristic of non-ideal frequency converter control is that the motor torque tends to vibrate either at the supply current frequency or at a frequency twice as high as the supply frequency. This phenomenon is particularly undesirable in elevators, in which even slight torque vibrations noticeably impair the quality of elevator travel.

There are several reasons for such vibration, including phase asymmetry of the motor, deviations in the d.c. components of different phases, eccentricity of the motor, asymmetry of the coil spans, inductive interference, and so on.

It can be proved that the direct current flowing in the motor causes vibration at the frequency of the current and that phase asymmetry produces vibration at the frequency of the second harmonic. In a vector diagram combining the phases, divergent direct current components in different phases produce a resultant vector that remains stationary, alternately strengthening and weakening the rotating main flux of the motor. Correspondingly, phase asymmetry can be divided into two vectors rotating in opposite directions at the supply current frequency. These vectors encounter each other twice during a cycle, so the result is the second harmonic frequency of the supply current.

Both the direct current component of the supply current and phase asymmetry can be adjusted, thus minimising vibrations in the motor. The adjustment requires great skill, and it has to be done again each time when maintenance or repair

operations are carried out on the motor. This adjustment is particularly difficult to carry out from the machine room of the elevator.

The object of the present invention is to eliminate the drawbacks described above. A specific object of the present invention is to present a new type of method that makes it easier to minimise torque vibrations in an alternating-current motor.

As for the features characteristic of the invention, reference is made to the claims.

The method of the invention is preferably used in elevator systems to eliminate torque vibrations in an alternating-current motor controlled by a frequency converter. According to this method, the adjustment is performed by utilising a vibration spectrum descriptive of the properties of the elevator. The vibration spectrum is obtained on the basis of the mechanical output of the motor. From the vibration spectrum, the characteristic frequency of the motor supply current as well as the harmonic frequencies are separated, the amplitude of which is minimised in the method of the invention. The essential point in the invention is that the measurement of the vibration spectrum is carried out using a measuring element placed in a position where the essential quantity measured is the motor torque or the vibration propagating to the structures as a result of fast changes in the torque.

In a preferred embodiment of the invention, the measured vibration spectrum is filtered by means of adjustable filters to separate the characteristic frequency of the motor supply current and its harmonics from the spectrum. The filters are preferably automatically adjusted based on motor supply current frequency data.

In a preferred embodiment of the invention, torque vibrations in the motor are minimised by means of the direct current supplied into the motor by the frequency converter. The regulation is based on the characteristic frequency of the current supplied into the motor. The regulation does not aim at making the direct current components of the frequency converter output equal to each other, but instead the torque vibrations in the whole system are minimised.

In a preferred embodiment of the invention, torque vibrations in the motor are minimised by adjusting the phase symmetry of the frequency converter. The phase symmetry can be influenced e.g. by adjusting the phase amplitude or the phase difference. The regulation is based on the harmonics of the current supplied into the motor. Of the vibration spectrum, preferably the second harmonic frequency is examined in conjunction with a three-phase system.

In a preferred embodiment of the invention, the torque of the elevator motor is measured to produce a vibration spectrum. The motor torque can be considered equal to its mechanical output.

In a preferred embodiment of the invention, a vibration spectrum descriptive of the properties of the elevator is obtained via a measurement using a spring sensor. In this case, the measurement is performed directly on the basis of the motor torque.

In a preferred embodiment of the invention, the vibration spectrum descriptive of the properties of the elevator is obtained via a measurement using a brake balance. The measurement is performed directly on the basis of the motor torque.

In a preferred embodiment of the invention, the vibration spectrum descriptive of the properties of the elevator is obtained via a measurement using a tachometer. The tachome-

ter is connected directly to the motor shaft or to a part fixedly connected to it.

In a preferred embodiment of the invention, the vibration spectrum descriptive of the properties of the elevator is obtained via a measurement using a pulse counter monitoring the travelling speed of the elevator.

In a preferred embodiment of the invention, the vibration spectrum descriptive of the properties of the elevator is obtained via a measurement using an acceleration transducer. By means of the acceleration transducer, vibrations are measured e.g. from the motor casing or from the elevator car.

In a preferred embodiment of the invention, the vibration spectrum descriptive of the properties of the elevator is obtained via a measurement using an acceleration transducer attached to the motor casing or to the elevator car.

The invention provides the advantage that all factors, including those independent of the frequency converter, are taken into account, for in essence it is the motor torque that is being measured. The exacting and time-consuming manual adjustment of trimmers can be omitted. This allows easier installation of spare parts. The method is also economical in respect of price because no essential expensive parts need to be added. The method of the invention can be used in conjunction with traction sheave elevators and drum drive elevators.

In the following, the invention will be described by the aid of a few examples of its embodiments by referring to the attached drawing, which presents the method of the invention in the form of a block diagram.

Based on the output of the alternating current motor 1, a measuring element 2 performs a measurement producing the

vibration spectrum to be examined. The measuring element 2 may be e.g. a spring sensor, a brake balance, a tachometer, a pulse counter attached to the motor shaft, an acceleration transducer attached to the motor casing, or an acceleration transducer attached either to the elevator car or to a part structurally connected to it. The essential point is that the motor torque vibrations are discernible in the vibration spectrum.

From the vibration spectrum obtained from the measuring element 2, a band-pass filter 3 separates the motor current and its second harmonic. The band-pass filter 3 receives information about the motor supply current frequency from a regulator unit 4. The filtered signal is taken further to the regulator unit 4.

The motor 1 is controlled by three control units 5 - 7, each taking care of a different phase voltage. Control unit 7 determines the curve form and frequency of the phase voltage by means of controller 17 in accordance with a frequency reference 18. The amplitude is determined by multiplying the curve form in accordance with an amplitude reference 19 in a multiplier unit 14. Control units 6 and 7 have corresponding functions, controllers 15 and 16, and multiplier units 12 and 13.

According to the invention, control units 5 and 6 are additionally provided with two adders. Adders 10 and 11 are connected to the amplitude reference. Adders 8 and 9 are directly connected to the phase voltage. Thus, adders 10 and 11 influence the phase voltage amplitude of the frequency converter, while adders 8 and 9 influence the direct current component of the phase voltage of the frequency converter.

The adders receive their values from the regulator unit 4. The regulator unit 4 is designed to minimise the signals it receives from the band-pass filter 3. A possible operating

principle is as follows: The regulator unit 4 sets the frequency of the band-pass filter 3 to a value corresponding to the supply current frequency. The signal amplitude is measured during elevator travel. At first, by adjusting adder 8, the minimum amplitude value is determined. The same is repeated with adder 9. This procedure is carried on between adders 8 and 9 until no significant change occurs any more. Next, the frequency of the band-pass filter 3 is set to a value corresponding to the second harmonic frequency of the supply current. The amplitude is minimised in a corresponding manner using adders 10 and 11.

To minimise the vibrations in the elevator, the elevator is run in adjustment mode, which may be implemented as a separate initialisation operation or as an automatic operation carried out at certain intervals. To minimise the values, it is possible to utilise adaptive regulation, fuzzy logic algorithms or determination of weighting factors by using neural networks.

The invention is not restricted to the examples of its embodiments described above, but many variations are possible within the scope of the inventive idea defined by the claims.

CLAIMS

1. Method for eliminating torque vibrations in a frequency converter controlled a.c. motor used in an elevator system, **characterised** in that the torque vibrations are minimised on the basis of the characteristic frequency of the motor supply current and its harmonics, which are separated from a suitable vibration spectrum descriptive of the elevator properties.

2. Method as defined in claim 1, **characterised** in that the characteristic frequency of the current supplied into the motor and its harmonics are separated from the vibration spectrum using adjustable filters.

3. Method as defined in claim 1 or 2, **characterised** in that, to minimise torque vibrations in the motor, the d.c. voltage of the frequency converter is adjusted by means of the characteristic frequency of the current supplied into the motor.

4. Method as defined in claim 1 or 2, **characterised** in that, to minimise torque vibrations in the motor, the phase symmetry of the frequency converter is adjusted by means of the harmonics of the current supplied into the motor.

5. Method as defined in any one of claims 1 - 4, **characterised** in that the torque of the elevator motor is measured to produce a vibration spectrum.

6. Method as defined in any one of claims 1 - 4, **characterised** in that a vibration spectrum descriptive of the elevator properties produced via a measurement using a spring sensor.

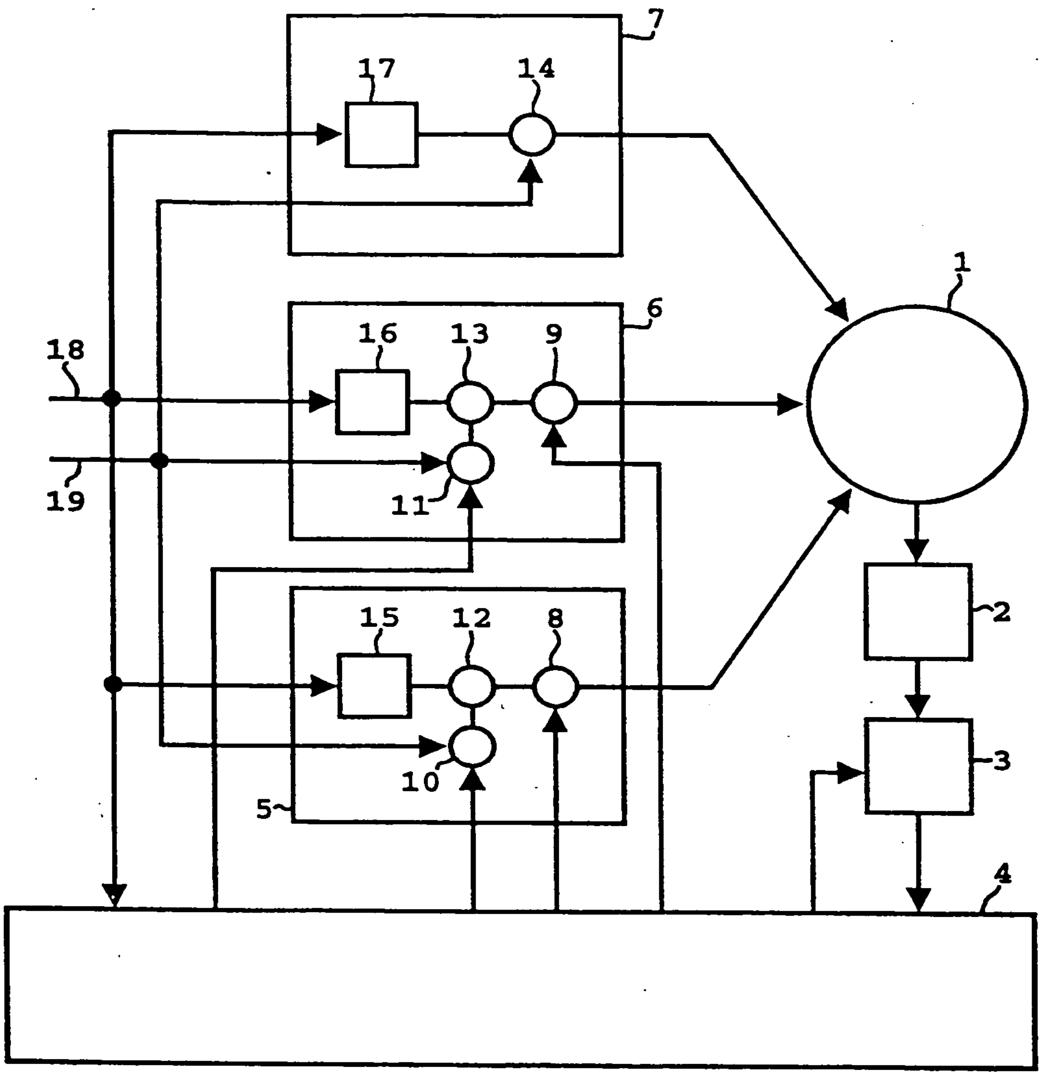
7. Method as defined in any one of claims 1 - 4, **characterised** in that a vibration spectrum descriptive of the eleva-

tor properties produced via a measurement using a brake balance.

8. Method as defined in any one of claims 1 - 4, **characterised** in that a vibration spectrum descriptive of the elevator properties produced via a measurement using a tachometer.

9. Method as defined in any one of claims 1 - 4, **characterised** in that a vibration spectrum descriptive of the elevator properties produced via a measurement using a pulse counter.

10. Method as defined in any one of claims 1 - 4, **characterised** in that a vibration spectrum descriptive of the elevator properties produced via a measurement using an acceleration transducer attached to the motor casing or to the elevator car.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INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 98/00894

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H02P 7/00, H02P 7/36, B66B 1/30
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B66B, H02P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2266976 A (GOLDSTAR INDUSTRIAL SYSTEMS CO LTD), 17 November 1993 (17.11.93), abstract --	1-10
P,A	GB 2313928 A (OTIS ELEVATOR COMPANY), 10 December 1997 (10.12.97), abstract -- --------	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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International application No.
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